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PHYTOCOENOTICAL AND ECOLOGICAL CHARACTERIZATION OF BEECH FORESTS (*FAGUS SYLVATICAE L.*) OF UKRAINE AND POSSIBILITY TO EXPAND THEIR AREA DUE TO GLOBAL WARMING

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Summary

In the late Holocene (4 thousand years ago), there were favorable environmental conditions for the growth of beech and spread of beech forests formation in the western regions of Ukraine in a warm and humid climate. Continuous and disjunctive area of beech forest covered the area of 1,445 thousand ha, within which beech forests expanded in an area which was around 525 thousand ha. During the past two centuries due to various types of human impact beech forests have changed significantly both quantitatively and qualitatively. Those changes had negative impact on their coenotic structure. Within the natural habitat of beech forest the beech area decreased by 129.9 thousand ha, or 22.2% (relative to their current area).

Ukraine is one of the least wooded countries in Europe (forest cover is only 15.7%). The reproduction of beech forests and the expansion of beech forest area is an important silvicultural and economic aim. Real opportunities for beech forests exist in moderately humid climate zone of West Ukraine. In Ukrainian areas of Roztochya, Opillya and Podillya, remains of natural beech forest are preserved. These phytocoenoses line out the Eastern European border area of beech forests. There is an interest to determine their dynamic trends due to global warming; furthermore such derivatives of natural biogeocenosis are subject to preservation.

Key words: beech forest, hydrothermal coefficient, coenotical structure, climax community, edatope, hydrotope.

INTRODUCTION

The broad-leaved forests of Ukraine, including beech forests, have undergone considerable qualitative and quantitative changes during last two centuries that severely affected their ecological stability. The area of beech forests has decreased by 129,900 ha or by 22.2% (compared with the present day forest cover). Therefore, the regeneration of beech forests and the increase of their area is currently an important economic and ecological problem. The real possibilities of solving it exist in humid and semi-humid climatic zones of Western Ukraine, which are favorable for growth of beech.

Dynamic trend change for beech forests as a result of global warming is relevant for the Polish Carpathians as well, where monodominant pure beech (*Fagetea sylvaticae*) and mixed fir-beech forests (*Abieto-Fagetum*) spread. It also concerns the flat hornbeam beech (*Carpineto-Fagetum*) phytocenosis too.

REGIONS AND METHODS OF INVESTIGATION

Forestry, geobotanical, chorological, and ecological research was carried out on the territory of the Ukrainian Carpathians, where monodominant beech forests show a zonal spreading on a vast area, as well as in Opillya and Western Podillya, where beech forests are preserved on the Eastern European boundary of their habitat. Therefore, they present an extraordinary interest for studying beech vitality and trends of its dynamics in connection with global climate warming. The research was carried out in protective and industrial forests by using stationary, semi-stationary, and route methods. Cartographic (partly aerocosmic) and taxational data of post-war, and in some cases of pre-war period, and partially those from archives were used.

PHYTOCOENOTICAL AND ECOLOGICAL CHARACTERIZATION OF BEECH FORESTS

The beech forests in Western Ukraine present an interest both in historical and botanical-geographical aspect. Therefore, they have long been in the centre of attention of botanists and foresters [Domin, 1931; Kosets, 1971; Miklusz, 2011; Molotkov, 1966; Parpan, 1994; Smagliuk, 1968; Stoyko, Barna, 1966; Stoyko, 1992, 2005; Szafer, 1935; Tretiak, 1960; Zlatnik, 1938].

The present day beech (*Fagus sylvatica* L.) area in Ukraine was formed in the middle Holocene by migration from two refugial areas – Western Carpathian and Eastern Podillyan. Now the area of beech as a mountain species embraces the mountainous Carpathian and hilly Opillya-Podillyan natural regions (Fig. 1).

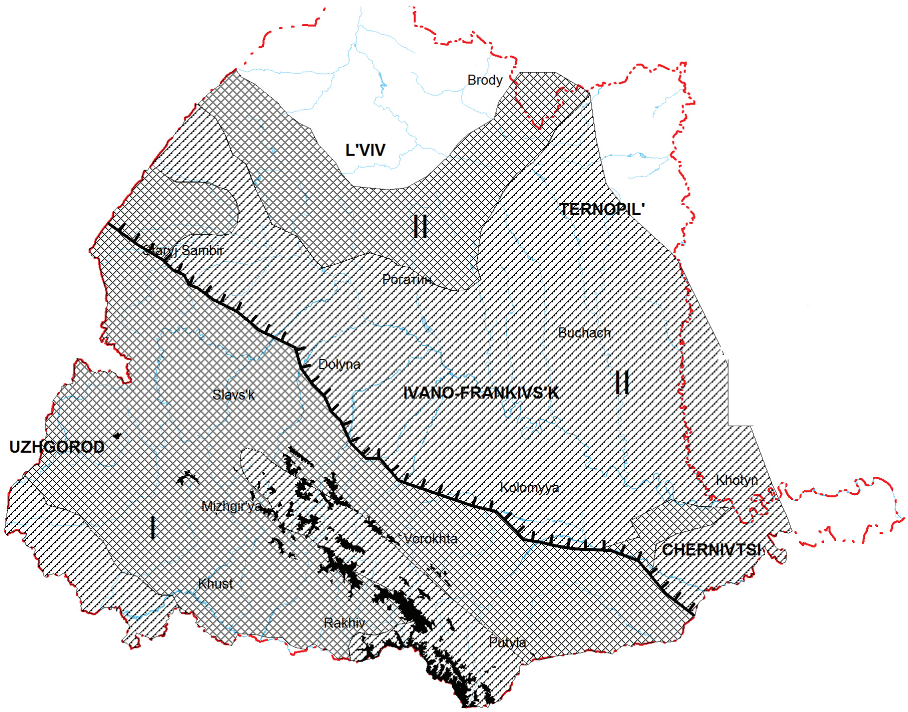

Figure 1. The area of beech forest in the Ukrainian Carpathians; I – Carpathian region, II – Opillya and Podillya regions, – dominant and subdominant, – assectator, – alpine zone without Beech, – border of Carpathian region.

In the Carpathians, beech is spread within the altitude of 300 (400)-1250 (1387) m a.s.l., in Opillya and Podillyan areas – in the range of 300-400 (450) m a.s.l. The above-mentioned regions are characterized by different climatic, soil, lithological, and orographic conditions influencing the character of beech distribution, its vitality and coenotical structure of the communities (Figs. 2-4). Depending on the ecological conditions and coenotical structure of phytoceonoses, we have established three types of beech areas: a) an area, where beech plays the dominant part in forest coenoses (climax communities); b) an area, where beech plays the co-dominant part; and c) an area, where beech plays the asectatorial (coeno-component) part.

Figure 2. Monodominant beech virgin forest (*Dentario – Fagetum*). Stuzhytske forestry, Uzhansky National Natural Park (photo: UNPP).

Figure 3. Stage of destruction in virgin beech forest. Uzhansky National Natural Park (photo: UNPP).

The most important criterion to determine the chorological and coenotical structure of beech forest in a complex of ecological factors is T. Selyaninov's [1937] hydrothermal coefficient, which is determined on the basis of correlation of atmospheric precipitation and evaporation [13].

It was established that beech forests of Ukraine are spread in the range of hydrothermal coefficient from 1.5 to 3.76. In the Opillya – Podillya region (a more extensive chorological alliance), beech grows in the range of hydrothermal coefficient 1.5-1.8. Co-dominant and asectatorial types of beech area are prevailing in this region. In the more humid region of the Carpathians, beech is spread in the range of hydrothermal coefficient 1.9-3.7. The dominant type of the area is prevailing here, while in a colder climate in the mountains (1,200 – 1,400 m), a co-dominant type prevails. It should be noted that in the Carpathian region, the hydrothermal coefficient indicates the altitude vegetational belts and borders between sub-chorions Transcarpaticum, Intracarpaticum, and Praecarpaticum. Each of them is characterized by its own type of beech area.

Figure 4. Elfin woodland of beech forest on Kremenets Mountain (1221 m a.s.l). In 130 years the average height of model beech is 6.2 m in the Uzhansky National Park (photo S.M. Stojko).

The climatic conditions, geological structure, and lithological base define various types of beech forests soils. The general regularity of beech forests associated with various genetic types of soils can be traced. In the Carpathians, beech forests on flysch lithological base tend to grow on light-brown and brown forest soils. Monodominant beech forests and hornbeam-beech forests are associated with light-brown, while the dark coniferous beech forests are associated with brown soils. Hornbeam-spruce-beech and oak-beech phytocoenoses of the foothills are associated with podzol soils on alluvial and delluvial sediments. In Opillya and Podillya, the subformations of oak-hornbeam-beech and hornbeam-beech forests are ecologically associated with light-grey and grey soils on carbonate and non-carbonate loess.

Edaphically different beech forest localities in various types of landscapes are also distinguished according to the main physical-chemical properties of pedosphere. Beech forest soils are characterised by a wide range of actual pH (3,0-7,0) and hydrolithic acidity (from 3 to 38.0 mg eqv. per 100 g of soil), by varying degree of saturation with bases (from 13 to 94%), and retention of organic substance (2.5 to 15% in 0-10 cm horizon).

Ecotopic structure of beech forests also shows that they are different in mountainous Carpathian and hilly Opillya-Podillyan chorions. In the ecotopogram of the Carpathians, beech forests-rich trophotopes cover 56.4% of the area, and in Opillya-Podillyan region they cover 93.3%. An opposite phenomenon is observed when taking into account the ecotope's moisture characteristics. In the mountain conditions, beech forests are associated with moist edatopes on 85% of the area. On the hilly landscapes, beech forests are associated with mesohygrophyte edatopes on 66% of the area. This analysis shows that in the mountain regions the increased moisture of soil and air is a certain compensating factor and that beech forests spread in mesotrophic and rarely in oligotrophic conditions.

An ecological estimation of beech forests' coenocomponents is also of interest. Its data show that when hygrophylous properties are taken into account, mesophytes are prevailing (81-89%), while when trophic properties are taken into account, eutrophic and mesotrophic species prevail (82%). They testify of rich edaphic conditions of beech formations.

Ukrainian beech forests, unlike oak forests, present coenotically „closed" associations; therefore, they are distinguished by relatively limited inclusions of other coenocomponents. In the ecological conditions of the Carpathians, optimal for beech growth, monodominant climax beech forests prevail. Polydominant phytocoenoses are spread here only in warm and dry plains and foothill regions, as well as in cold mountain landscapes.

In the Opillyan-Podillyan chorion, which is drier and less favorable for beech growth, poly-dominant beech forests prevail, but without inclusion of spruce and fir. Aboriginal fir occurs in beech forests only rarely in Opillya region (the Pidvysoke forest reserve in the Romaniv forestry).

To learn phylocoenogenesis (historical development) of beech forests and the character of successive processes, it is important to define their coenotical structure. Its determination is also necessary to establish the typological units and application of the differentiated methods of forestry on a typological basis.

In the coenotical structure of beech forests formations, the following subformations (forest type groups) have been singled out: *Fagetea sylvaticae*, *Carpineto-Fagetum*, *Querceto roboris-Fagetum*, *Querceto petraeae-Fagetum*, *Carpineto-Abieto-Fagetum*, *Acereto pseudoplatanae-Fagetum*, *Taxoso-Abieto-Fagetum* (only in the Kniazh-Dvir reserve on carboant soils), *Pineto-Fagetum* (very rare, only in the Roztochya region on sand soils), *Abieto-Fagetum*, *Piceeto-Abieto-Fagetum*, and *Piceeto-Fagetum*.

Forestry in Ukraine is based on the principles of P.S. Pogrebnyak's [1955] typological system. According to its principles, forest types are determined by means of tree species ediphycators, trophotopes, and hygrotopes. P.S. Pogrebnyak's edaphic system includes 4 trophotopes (oligotrophic, oligo-mesotrophic, mesotrophic, and eutrophic) and 6 hygrotopes (xerophilous, meso-xerophilous, mesophilous, meso-hygrophilous, hygrophilous, and ultra-hygrophilous). According to the above-mentioned typological principles, 32 types have been singled out in beech forests. The typological analysis shows that *Fagus sylvatica* is a relatively stenotope-like species. Its types are associated only with eutrophic, mesotrophic and very rarely oligo-mesotrophic trophotopes. Depending on the humidity of the habitat, it is associated with mesophilous, mesohygrophilous, and very rarely hygrophilous hydrotopes. Eutrophic mesophilous and mesohygrophilous edaphic conditions are most favorable for beech growth. The climax associations are formed in the above-mentioned conditions.

Ukrainian beech forests have undergone far less territorial changes than oak forests, which is due to their high vitality and broad distribution in the mountain regions. During the last two centuries, the area of beech forests (within the boundaries of the present day forest cover) decreased by 129,000 ha, or by 22.2% (Table 1). The main reason for such transformation is „coniferization" of broad-leaved forests as a result of monoculture forestry. The data given in Table 2 shows that spruce trees were intensively cultivated in the habitat of purely beech, hornbeam-beech, and spruce-fir-beech forests. As a result of such changes, destabilization of forest ecosystems in which catastrophic windfalls, snow breaks and invasions of entomofauna periodically occur in Ukraine [Holubec, 1978]. The number of beech undergrowth and its height groups in mono – and polydominant beech forests are presented in Table 3.

Table 1. The area of beech forests in Ukraine in present-day and post time (within the state forests, thousand ha)

Formation, subformations	Regions								Change of area of beech forests in comparison with present day	
	Carpathians				Opillya-Podillya		Total area			
	South-Western macroslope		North-Eastern macroslope							
	present-day	past time	present-day	past time	present-day	past time	present-day	past time	thousand ha	%
Fagetea sylvaticae	160.5	181.4	10.7	13.2	-	-	171.2	194.6	-23.4	12.0
Carpineto-Fagetum	66.4	81.8	4.6	5.9	11.9	17.6	82.9	105.3	-22.4	21.3
Querceto roboris-Fagetum and Querceto – petraeae – Fagetum	4.6	6.1	7.4	11.0	67.9	98.9	79.9	116.0	-36.4	31.1
Carpineto-Abieto-Fagetum	-	-	6.8	9.2	-	-	6.8	9.2	-2.4	26.1
Abieto-Fagetum	8.1	10.7	22.4	30.3	-	-	0.5	40.9	-10.3	25.1
Piceeto-Abieto – Fagetum	23.7	31.5	44.9	70.4	-	-	68.6	101.9	-33.3	32.7
Piceeto – Fagetum	5.2	6.7	-	-	-	-	5.2	6.7	-1.5	22.4
Acereto pseudoplatanae-Fage-tum	10.3	10.4	-	-	-	-	10.3	10.4	-0.1	1.0
Pineto-Carpineto – Fagetum	-	-	-	-	0.5	0.8	0.5	0.8	-0.3	37.5
Total area	278.8	328.6	96.8	139.9	80.3	117.3	455.9	585.8	-129.9	22.2

Table 2. Data of beech forests transformation (within the state forests, thousand ha)

Formation, subformations	Total area	The main dominant species of frees in beech forests									
		Fagus sylvatica	Quercus robur	Quercus petraea	Quercus borealis	Carpinus betulus	Betula pendula	Picea abies	Abies alba	Pinus sylvestris	Other species
Fageta sylvaticae	194.6	171.2	2.9	1.8	0.2	0.5	0.4	15.0	0.3	0.3	2.0
Carpineto-Fagetum	105.3	82.9	6.0	3.3	0.4	3.0	1.2	6.2	0.2	0.1	2.0
Querceto roboris-Carpineto-Fagetum and Querce-to petraea – Fagetum	116.0	79.9	17.7	0.5	2.2	6.7	2.5	2.1	0.3	1.6	2.5
Carpineto-Abieto-Fagetum	9.2	6.8	0.6	-	-	0.2	0.1	0.8	0.3	0.2	0.2
Abieto-Fagetum	90.4	30.5	0.5	-	0.1	0.1	-	6.5	2.0	1.0	0.2
Piceeto-Abieto – Fagetum	101.5	68.9	0.3	-	-	0.1	0.3	26.7	4.7	0.6	0.6
Piceeto – Fagetum	6.7	5.2	-	-	-	-	-	1.4	-	-	0.1
Acereto pseudoplatanae-Fagetum	10.4	10.3	0.1	-	-	0.1	0.1	-	-	-	-
Pineto-Carpineto – Fagetum	0.8	0.5	-	-	-	-	-	-	-	-	-
Total area	585.8	455.9	28.1	5.6	2.9	10.7	4.6	58.8	7.8	3.8	7.6

Table 3. Number of undergrowth and its height groups in mono – and polydominant beech forests

Formation, subformations	Number of research plots	Number of undergrowth of beech and other species, thousand per/ha				
		Beech	All woody species together	Height groups, m		
				< 0.5	0.51-1.5	>1.5
Fageta sylvaticae	28	23.9±3.4	29.7±3.6	20.3±2.78	6.5±1.23	2.9±0.21
Abieto-Fagetum	14	4.8±1.27	8.8±1.8	5.3±1.52	3.1±0.94	0.35±0.13
Piceeto-Abieto – Fagetum	19	9.1±1.70	17.3±2.5	13.5±2.59	2.6±0.60	1.2±0.38
Querceto roboris-Carpineto – Fagetum	61	9.5±1.74	19.8±2.9	13.0±2.06	4.6±0.89	2.2±0.46

OPPORTUNITIES TO INCREASE THE AREA OF BEECH FORESTS AT THEIR EASTERN EUROPEAN BORDER

The crucial environmental factor for forest ecosystems are soil and climate, particularly temperature and humidity. In consequence of different types of human impacts on the biosphere, in particular emissions of greenhouse gases – CO_2, CH_4, and N_2O – in the last century, the processes of global warming and climate change are observed. According to the Research Intergovernmental Panel on Climate Change (IGPCC) established by the World Meteorological Organization (WMO) and the Environment Program of UN (EPUN) centenary (for the period 1906-2005) a linear trend was found which shows an increasing annual temperature in atmosphere of 0,74ºC (Fig. 5) [Izmenenije klimata, 2007]. This correlates with the Ukrainian National Report on Climate Change, which shows that the average annual temperature increased to 0.7ºC and annual rainfall of 4-5 mm. The average January temperature has increased by 1.5-2.5ºC [Klimat Ukrainy, 2007].

Thus the annual temperature amplitude is reduced, and continentality of climate too. These climatic changes have a favorable effect on the ecological condition of beech forests.

Comparative chorological studies of *Fagus sylvatica* within its vertical distribution in the Carpathians and on the Eastern-European boundary in Podillya enabled to establish the trend to widening its area in the present day climatic conditions. Beech undergrowth is actively occupying ecological niches in oak forests of *Quercus robur* and *Quercus petraea*, as well as in mixed hornbeam-beech, pine-beech, maple-beech, beech-fir-spruce phytocoenoses. It takes place due to specific ecobiological peculiarities of beech in ontogenesis. European beech until senile age is characterized by intense fruiting and natural regeneration. As it can be seen in Table 3, beech trees account for 50% of the undergrowth in poly-dominant phytocoenoses. Their undergrowth is able to develop a good sprout and root system even after 50-60 years of shading, if given enough sunlight.

The analysis of undergrowth species variety in mono – and poly-dominant economic forests partially transformed through anthropogenic impact may be of interest. As seen from the data given in Table 3, dense beech undergrowth is characteristic for all forest type groups. The highest diversity of undergrowth species can be found in mixed broad-leaved forests, which is due to the favorable sunlight conditions.

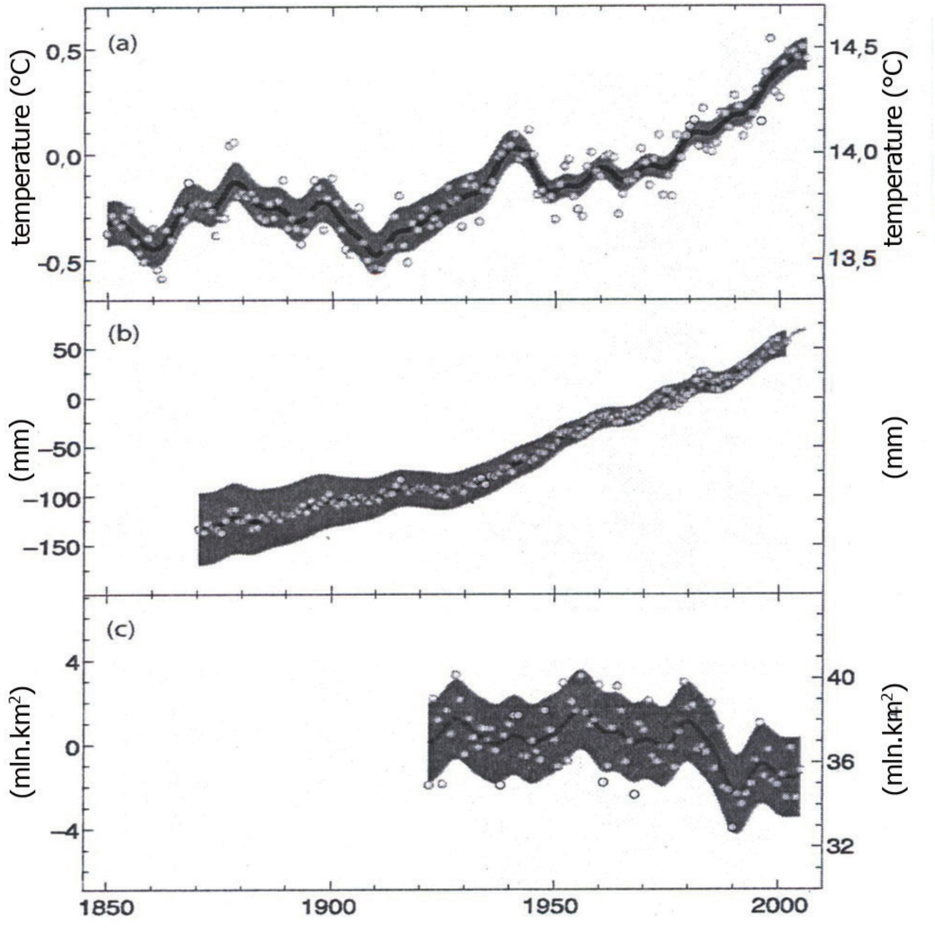

Figure 5. The change of temperature, see level and area of snow cover in northern hemisphere; a – the change of average temperature on the earth surface, b – global average of see level, c – the area of snow cover.

Beech admixture, its phytomeliorative and ecostabilizing function (against windfalls) in oak and spruce plantations proves especially desirable.

The most effective biotechnique and economical measures that ensure preservation of beech undergrowth and fulfilling of its protective function is the „Plenterwald" forestry system whose ecological principles were founded by

H. Leibundgut (1978) and H. Mayer and E. Ott (1991). Therefore, it should be recommended for application in protective mountain beech forests. In harvested beech forests, the system of gradual felling, developed in the Carpathian region by P. Molotkov (1966), J. Saban (1987), and V. Parpan (1994), proved to be appropriate.

PROTECTION OF NATURAL BEECH FORESTS

Especially interesting are the natural beech forests. In Western Podillya (Sataniv forestry) a natural massif of hornbeam beech (Carpineto-Fagetum) is preserved; this hornbeam forest is located on the boundary of the Eastern European beech forest habitat. In order to protect this forest stand the national reserve "Satanivska Buchyna" with 308 ha was established.

The remoteness of the mountainous areas of Transcarpathia preserved large areas of virgin beech forests. As a result phylogenesis in virgin forest ecosystems developed a capacity for self-recovery, self-regulation and biological self-defense. Therefore, they are valuable models for the forming of forests close to nature. The virgin beech forests are protected in the Carpathian Biosphere Reserve, Uzhansky National Park and other protected objects. In Transcarpathia an area of 23,582 ha is preserved. In the National Park of Slovakia an area of 5,696 ha is protected. 2007 included the Committee on World Heritage "The beech forests of the Eastern Carpathians" with an area of 29,278 hectares to the list of World Natural Heritage sites. Those natural beech forests are important to improve the gene pool and phytocoenotic pool for beech forests in Central Europe. In virgin beech forests of the Carpathian Biosphere Reserve and Uzhansky National Park the Ukrainian, Swiss, Czech and Slovak foresters conduct environmental studies of forest processes.

CONCLUSIONS

Beech forests of *Fagus sylvatica* are spread only in humid and semi-humid climatic zones of Western Ukraine in the range of H.Selyaninov's hydrothermal coefficient range 1.50-3.76. Their area decreased as a result of "coniferization" of broad-leaved forests, their transformation into meadows and due to intensive pastoral effect. The most large-scale beech succession occurred in the coniferous beech forests. In present-day climatic condition, intensive generative regeneration is observed within the whole beech habitat (9-20 thousand pieces per ha of the 0.5-1.5m high undergrowth). After the cessation of anthropogenic impact, a gradual occupation of ecological niches by beech trees can be observed both in mixed broad-leaved and coniferous phytocoenoses. The studies show that there are real prospects for increasing beech forests areas in the Carpathians, Precarpathian, Rostochya, Opillya, and partially Podillya regions. It is facilitated by the intense generative regeneration of beech, its high vitality and successful cultivation. Considering the global warming ways are discussed to increase the area of beech forests. The necessity of protection of the virgin beech forest is substantiated.

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